PERGAMON

Global Environmental Change 11 (2001) 203–216

GLOBAL ENVIRONMENTAL CHANGE

www.elsevier.com/locate/gloenvcha

An overview of guidelines and issues for the monitoring, evaluation, reporting, verification, and certification of forestry projects for climate change mitigation

Edward L. Vine*, Jayant A. Sathaye, Willy R. Makundi

Energy Analysis Department, Environmental Energy Technologies Division, Lawrence Berkeley National Laboratory, 1 Cyclotron Road, MS 90-2000, Berkeley, CA 94720 USA

Received 6 May 1999

Abstract

Monitoring and evaluation of forestry projects is needed to accurately determine their impact on greenhouse gas emissions and other attributes, and to ensure that the global climate is protected and that country obligations are met. We present an overview of guidelines recently developed for the monitoring, evaluation, reporting, verification, and certification of forestry projects for climate change mitigation.[1] These guidelines are targeted to developers, evaluators, verifiers, and certifiers of forestry projects, and address several key issues, including methods for estimating gross and net carbon savings. The next phase of our work will be to develop a procedural handbook providing information on how one can complete monitoring, evaluation and verification forms. We then plan to test the usefulness of these handbooks in the real world.

Keywords: Monitoring; Evaluation; Reporting; Verification; Certification; Forestry; Climate change; Joint implementation; Clean development mechanism; Market transformation; Free ridership; Baseline; Environmental impacts; Socioeconomic impacts; Spillovers; Leakage; Free riders

1. Introduction

Because of concerns with the growing threat of global climate change from increasing concentrations of greenhouse gases in the atmosphere, more than 176 countries (as of October 7, 1998) have become Parties to the UN Framework Convention on Climate Change (FCCC) (UNEP/WMO, 1992). The FCCC was entered into force on March 21, 1994, and the Parties to the FCCC drafted the Kyoto Protocol for continuing the implementation of the FCCC in December 1997 (UNFCCC, 1997). The Protocol requires developed countries to reduce their aggregate emissions by at least 5.2% below 1990 levels by the 2008–2012 time period.

The Kyoto Protocol includes two project-based mechanisms for activities across countries. Article 6 of the Protocol allows for joint implementation (JI) projects between developed (Annex I) countries: i.e., project-level trading of emissions reductions ("transferable emission reduction units") can occur among countries with GHG emission reduction commitments under the Protocol. Article 12 of the Protocol provides for a "Clean Development Mechanism" (CDM) that allows legal entities in the developed world to enter into cooperative projects to reduce emissions in the developing world for the benefit of both parties. Developed countries will be able to use certified emissions reductions from project activities in developing countries to contribute to their compliance with GHG targets. The key provisions of the Kyoto Protocol remain to be developed in more detail as negotiations clarify the existing text of the Protocol.

Projects that are to be undertaken within the CDM or under JI will involve several tasks: project development and registration; project implementation; and monitoring, evaluation, reporting, verification and certification. There will most likely be different types of arrangements for implementing these projects: e.g. (1) a project developer might implement the project with his/her own money; (2) a developer may borrow money from a financial institution to implement the project; (3) a developer may work with an energy service company who will be

* Corresponding author. Tel.: + 1-510-486-6047; fax: + 1-510-486-6996.

E-mail address: elvine@lbl.gov (E.L. Vine).

[1] This article is based on a more detailed report conducted for the U.S. Environmental Protection Agency (Vine, Sathaye, and Makundi, 1999).

0959-3780/01/$ - see front matter
PII: S0959-3780(00)00058-3

Box 1
MERVC definitions

Estimation: refers to making a judgement on the likely or approximate stock of carbon, GHG emissions, and socioeconomic and environmental benefits and costs in the with- and without-project (baseline) scenarios. Estimation can occur throughout the lifetime of the project, but plays a central role during the project design stage when the project proposal is being developed.
Monitoring: refers to the measurement of carbon stocks, GHG emissions, and socioeconomic and environmental benefits and costs that occur as a result of a project. Monitoring does *not* involve the calculation of GHG reductions nor does it involve comparisons with previous baseline measurements. For example, monitoring could involve the number of hectares preserved by a forestry project. The objectives of monitoring are to inform interested parties about the performance of a project, to adjust project development, to identify measures that can improve project quality, to make the project more cost-effective, to improve planning and measuring processes, and to be part of a learning process for all participants (De Jong et al., 1997). Monitoring is often conducted internally, by the project developers.
Evaluation: refers to both impact and process evaluations of a particular project, typically entailing a more in-depth and rigorous analysis of a project compared to monitoring emissions. Project evaluation usually involves comparisons requiring information from outside the project in time, area, or population (De Jong et al., 1997). The calculation of GHG reductions is conducted at this stage. Project evaluation would include GHG impacts and non-GHG impacts (i.e., environmental, economic, and social impacts), and the re-estimation of the baseline, leakage, positive project spillover, etc., which were estimated during the project design stage. Evaluation organizes and analyzes the information collected by the monitoring procedures, compares this information with information collected in other ways, and presents the resulting analysis of the overall performance of a project. Project evaluations will be used to determine the official level of GHG emissions reductions that should be assigned to the project. The focus of evaluation is on projects that have been implemented for a period of time, not on proposals (i.e., project development and assessment). While it is true that similar activities may be conducted during the project design stage (e.g., estimating a baseline or positive project spillover), this type of analysis is estimation and not the type of evaluation that is described in this paper and which is based on the collection of data.
Reporting refers to *measured* GHG and non-GHG impacts of a project (in some cases, organizations may report on their *estimated* impacts, prior to project implementation, but this is not the focus of this paper). Reporting occurs throughout the MERVC process (e.g., periodic reporting of monitored results and a final report once the project has ended).
Verification refers to establishing whether the measured GHG reductions actually occurred, similar to an accounting audit performed by an objective, accredited party not directly involved with the project. Verification can occur without certification.
Certification refers to certifying whether the measured GHG reductions actually occurred. Certification is expected to be the outcome of a verification process. The value-added function of certification is in the transfer of liability/responsibility to the certifier.

responsible for all project activities, etc. While the flow of funds might change as a result of these different arrangements, the guidelines described in this paper should be of relevance for all parties, independent of the arrangement.

1.1. Purpose of MERVC guidelines

Monitoring, evaluating, reporting, verifying, and certifying (MERVC) guidelines are needed for joint implementation and CDM projects in order to accurately determine their impact on GHG and other attributes (see Box 1) (Vine and Sathaye, 1997). Implementation of MERVC guidelines is also intended to: (1) increase the reliability of data for estimating GHG impacts; (2) provide real-time data so programs and plans can be revised mid-course; (3) introduce consistency and transparency across project types, sectors, and reporters; (4) enhance the credibility of the projects with stakeholders; (5) reduce costs by providing an international, industry consensus approach and methodologies; and (6) reduce financing costs, allowing project bundling and pooled project financing.

These guidelines are important management tools for all parties involved in carbon mitigation. There will be different approaches ("models") in how the monitoring, evaluation, reporting, verification, and certification of forestry projects will be conducted: e.g., a project developer might decide to conduct monitoring and evaluation, or might decide to contract out one or both of these functions. Verification and certification will most likely be implemented by third parties. Similarly, some projects might include a portfolio of projects. Despite the diversity of responsibilities and project types, the Lawrence Berkeley National Laboratory's (LBNL) MERVC guidelines should be seen as relevant for all models and project approaches.

In the longer term, MERVC guidelines will be a necessary element of any international carbon trading system, as proposed in the Kyoto Protocol. A country could generate carbon credits by implementing projects that result in a net reduction in emissions. The validation of such projects will require MERVC guidelines that are acceptable to all parties. These guidelines will yield verified findings, conducted on an ex-post facto basis (i.e., actual as opposed to predicted project performance).

The Kyoto Protocol contains emissions targets for six major greenhouse gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). LBNL's MERVC guidelines only examine MERVC issues dealing with CO_2.

2. The MERVC process

Climate change mitigation projects to be undertaken within the CDM or under joint implementation will likely involve several tasks (Fig. 1). We expect that there will be different types of arrangements for implementing these projects: e.g. (1) a project developer might implement the project with his/her own money; (2) a developer might borrow money from a financial institution to implement the project; (3) a developer might work with a third party who would be responsible for many project activities; etc. While the flow of funds might change as a result of these different arrangements, the guidelines should be relevant to all parties, independent of the arrangement.

In Fig. 1, we differentiate "registration" from "certification". Certification refers to certifying whether the measured GHG reductions actually occurred. This definition reflects the language in the Kyoto Protocol regarding the CD M and "certified emission reductions". In contrast, when a host country approves a project for implementation, the project is "registered" (see UNFCCC, 1998).[2] For a project to be approved, each country will rely on project approval criteria that they developed: e.g. (1) the project funding sources must be additional to traditional project development funding source; (2) the project must be consistent with the host country's national priorities (including sustainable development); (3) confirmation of local stakeholder involvement; (4) confirmation that adequate local capacity exists or will be developed; (5) potential for long-term climate change mitigation; (6) baseline and project scenarios; and (7) the inclusion of a monitoring protocol (see Watt et al., 1995).

[2] In contrast to our interpretation, others believe certification occurs at the project approval stage, prior to implementation. We disagree, since certification can only occur after changes in carbon stock and energy use have been measured.

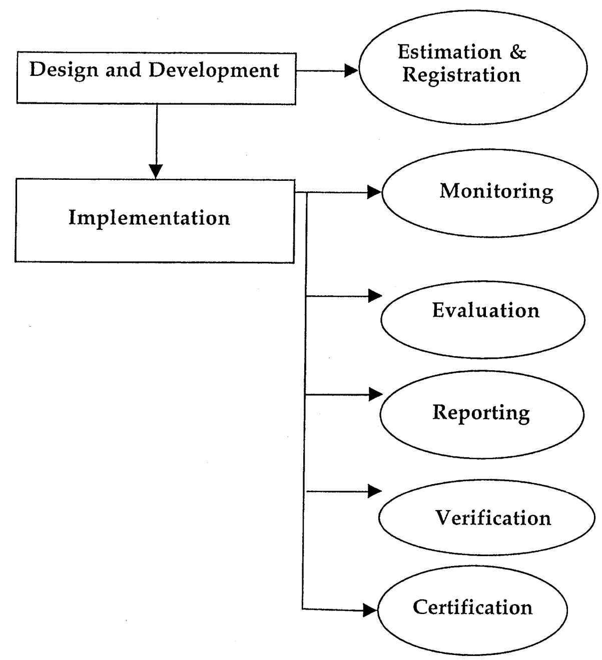

Fig. 1. Project tasks.

A country may also use different administrative or legal requirements for registering projects. For example, the project proposal (containing construction and operation plans, proposed monitoring and evaluation of changes in carbon stock, and estimated changes in carbon stock) might have to be reviewed and assessed by independent reviewers. After this initial review, the project participants would have an opportunity to make adjustments to the project design and make appropriate adjustments to the expected changes in carbon stock. The reviewers would then approve the project, and the project would be registered.[3] Individuals or organizations voicing concerns about the project would have an opportunity to appeal the approval of the project, if desired.

3. Conceptual framework

The analysis of changes in carbon stock occurs when a project is being designed and during the implementation of a forestry project. In the design stage, the first step is estimating the baseline (i.e., what would have happened to the carbon stock if the project had not been implemented) and the project impacts. Once these have been estimated, then the net change in carbon stock is simply

[3] Under this approach, the independent reviewers could be the same people who verify the project during project implementation (personal communication from Johannes Heister, The World Bank, Jan. 12, 1999).

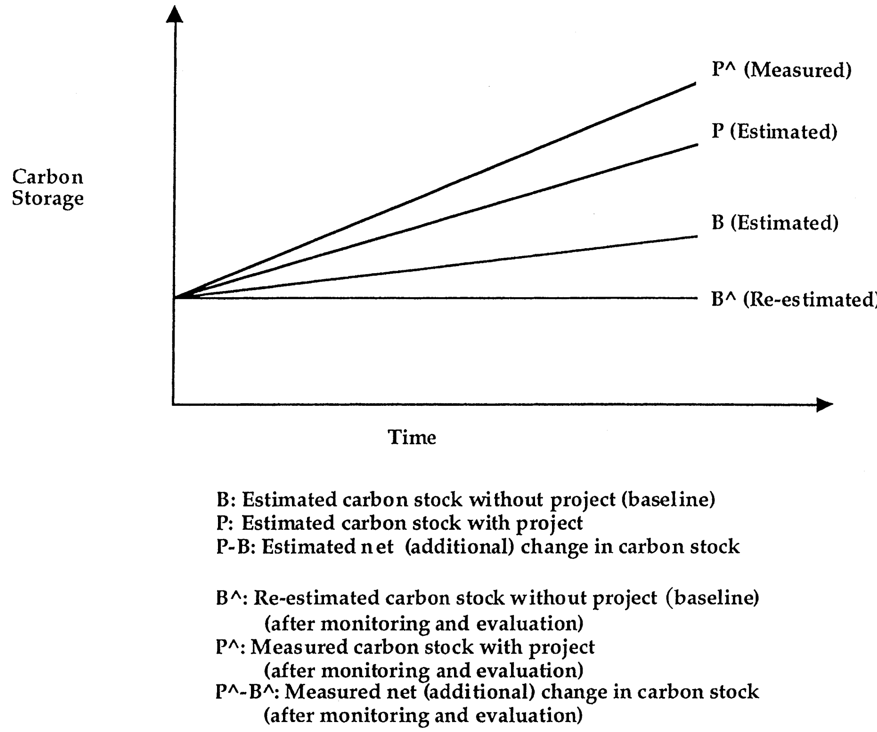

Fig. 2. Example of carbon storage over time.

the difference between the estimated project impacts and the baseline ($P - B$, in Fig. 2). After a project has started to be implemented, the baseline can be re-estimated and the project impacts will be calculated based on monitoring and evaluation methods. The net changes will be the difference between the measured project impacts and the re-estimated baseline ($P^\wedge - B^\wedge$, in Fig. 2). The example in Fig. 2 illustrates a case where measured carbon storage is greater than estimated as a result of a forestry project. On the other hand, carbon storage in the re-estimated baseline is lower than what had been estimated at the project design stage. In this case, the calculated net change in carbon storage is larger than what was first estimated. It is also possible that either $P^\wedge$ may be less than P and $B^\wedge$ may be more than B, or both might occur, making the net carbon storage less than estimated.

4. Monitoring and evaluation of GHG emissions

As an example of the type of monitoring and evaluation that is needed, we present in Fig. 3 an overview of one approach used in evaluating changes in the carbon stock. During the monitoring and evaluation stage, gross changes in the carbon stock are measured, using one or more of the following monitoring and evaluation methods: modeling, remote sensing, and field/site measurements. The baseline is also re-estimated, accounting for free riders.[4] The net change in the carbon stock is equal to the gross change in the carbon stock minus the re-estimated baseline.

4.1. Establishing the monitoring domain

The domain that needs to be monitored (i.e., the monitoring domain) is typically viewed as larger than the geographic and temporal boundaries of the project. In order to compare GHG reductions across projects, a monitoring domain needs to be defined. Consideration of the domain needs to address the following issues: (1) the temporal and geographic extent of a project's direct impacts; and (2) coverage of project leakage, positive project spillover, and market transformation.

The first monitoring domain issue concerns the appropriate geographic boundary for evaluating and reporting impacts. For example, a forestry project might have local (project-specific) impacts that are directly related to the project in question, or the project might have more widespread (e.g., regional) impacts (leading to project spillover and market transformation). Also, the MERVC of changes in the carbon stock of forestry projects can be conducted at the point of extraction (e.g., when trees are logged) or point of use (e.g., when trees are made into

[4] Free riders are project participants who would have installed the same energy-efficiency measures if there had been no project.

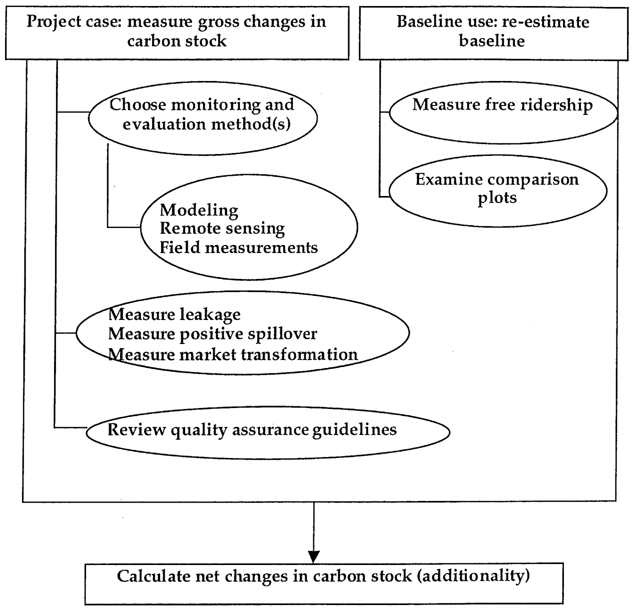

Fig. 3. Evaluation of forestry projects.

furniture), and when forests are later transformed to other uses (e.g., agriculture, grassland, or range). Thus, depending on the project developer's claims, one may decide to focus solely on the changes in the carbon stock from the logging of trees at the project site, monitor the changes over time from the new land use type, or account for the wood products produced and traded outside project boundaries.

The second issue concerns coverage of project leakage and positive project spillover, as discussed below. It is important to note that not all secondary impacts can be predicted. In fact, many secondary impacts occur unexpectedly and cannot be foreseen. And when secondary impacts are recognized, a commitment needs to be made to ensure that resources are available to evaluate these impacts.

One could broaden the monitoring domain to include off-site baseline changes (which are normally perceived as occurring outside the monitoring domain). Widening the system boundary, however, will most likely entail greater MERVC costs and could bring in tertiary and even less direct effects that could overwhelm any attempt at project-specific calculations (Trexler and Kosloff, 1998).

In the beginning stages of a project, the secondary impacts of a project are likely to be modest as the project gets underway, so that the MERVC of such impacts may not be a priority. These effects are also likely to be insignificant or small for small projects. Under these circumstances, it may be justified to disregard these impacts and simply focus on carbon savings from the project. This would help reduce MERVC costs. As the projects become larger or are more targeted to market transformation, these impacts should be evaluated.

4.2. Monitoring and evaluation methods

The measurement of a project's carbon fixation necessitates specialized tools and methods drawn largely from experience with forest inventories and ecological research. Monitoring and verifying carbon accumulation in forestry projects must be cost effective and accurate. Monitoring systems should be built upon standard forestry approaches to biomass measurement and analysis, and apply commonly accepted principles of forest inventory, soil science and ecological surveys. Specific methods and procedures should be assembled on a project-specific basis, with the types and extent of monitoring ultimately determined by the relative costs and quantity of carbon return by each measurement type.

Three general monitoring techniques can be used to monitor carbon fixed through forestry projects (based on MacDicken, 1997): (1) modeling, (2) remote sensing, and (3) field/site measurements, including biomass surveys (which includes research studies; surveys; the monitoring of wood production and end products; and forest inventories) and destructive sampling. Many of these techniques can be used together.

4.2.1. Modeling

Modeling the impacts of certain forestry practices on carbon flows into and out of forest carbon sinks can be used for estimating annual flows of carbon. The models are used to predict future carbon flows, but they do not measure the actual changes. The modeled estimates of carbon storage over time must be checked using one of the techniques described below (i.e., remote sensing with ground truthing or field/site measurement).

Models start from an estimate of a carbon stock for a specific forest type at a specific site. Then, based on information from forest practices, the models develop estimates of annual carbon flows. This approach relies on a series of highly simplified assumptions to estimate total carbon sequestration. For example, assumptions may include: the number of trees planted in either woodlots or agroforestry systems, initial stocking rates, mean annual stemwood volume increments, a biomass multiplier factor, and harvest rates. The assumptions are then inputted into a model to estimate the amount of sequestered carbon. The models need to be corrected/calibrated with measured data periodically as well as with other approaches. For example, approaches that estimate forest productivity by timber volume may be compared with other approaches, such as allometrically derived carbon estimates that incorporate relationships between tree or stand physiological parameters (e.g., diameter, height, weight, tapper (the change in diameter over height) and carbon content (Hamburg et al., 1997; Schroeder et al., 1997; Brown, 1997). The accuracy of these methods will depend on many factors, including the precision of the equations and the homogeneity of the forest (e.g., allometric equations are simpler and more accurate for homogeneous forests and more complex and less accurate for heterogeneous forests).

Some models are already available for simple conditions and standard treatments, such as tree planting on agricultural land. The Land Use and Carbon Sequestration (LUCS) model is a project-based computer model that tracks the changes in carbon density associated with land use changes (e.g., conversion of forested areas to agriculture) (Faeth et al., 1994; MacDicken, 1998). Direct measurements and default assumptions are used to calculate the changes and impacts. The LUCS model has been used in evaluating an agroforestry project on marginal hillsides in Guatemala (Trexler et al., 1992).

Soil organic matter and ecosystem models play an important role in understanding land management and soil organic carbon sequestration relationships and for projecting changes in soil organic carbon through time (Parton et al., 1995; Smith et al., 1997). The rate of soil organic carbon decomposition is usually well represented as a first-order process where the amount converted to CO_2 per unit time depends on the current size of the various soil organic carbon fractions times their rate constants (Smith et al., 1997). Since the amounts present in each carbon fraction depends on management history, these amounts must be accurately accounted if the model estimates of soil organic carbon dynamics are to be realistic. Generally, information on previous management history is less complete than needed to establish adequate initial conditions for models. When management history is well known for a period of at least 20–50 years, many soil organic carbon models do well in simulating management-induced soil organic carbon changes (Smith et al., 1997). Model validation remains an important step for validating models assumptions.

The Graz/Oak Ridge Carbon Accounting Model (GORCAM) is another model that can be used to examine the impact of forestry projects on carbon emissions (Schlamadinger and Marland, 1996). GORCAM provides a simplified description of carbon stocks and flows associated with the management of forests. GORCAM calculates carbon accumulation in plants, in short- and long-lived wood products, in fossil fuels not burned because biofuels are used instead, and in fossil fuels not burned because production and use of wood products requires less energy than does production and use of alternative materials that provide the same service (Marland et al., 1997). GORCAM has been used to evaluate the impact on carbon emissions by biofuel district heating systems being installed or proposed in Vermont (McLain, 1998), as well as estimating the amount of carbon sequestered by a sustainable forestry management project in Mexico (Bird et al., 1998).

More complex but promising models are being developed (USDOE, 1994). Simple modeling requires relatively little time and effort, however, the gross estimates are probably neither accurate nor precise (MacDicken, 1997). In general, field/site measurements are preferred over standard tables and computer models, because site-specific field studies provide higher quality data and thus higher credibility, although at a higher cost.

4.2.2. Remote sensing

Remote sensing (along with ground-based measurements) can be used to monitor land area changes, map vegetation types, delineate strata for sampling, and assess leakage and base case assumptions. Remote sensing is defined as the acquisition of data about an object or scene by a sensor that is far from the object (Colwell, 1983; see also Slater, 1980; Swain and Davis, 1978; Wilkie and Finn, 1996). Aerial photography, satellite imagery, and radar are all forms of remotely sensed data. Usually, remote sensing refers to the following two types: (1) "high-level" remote sensing that uses satellite imagery, and (2) "low-level" remote sensing that relies on aerial photography.

4.2.2.1. High-level remote sensing. Many national and international projects and programs have made use of remote sensing with satellites for land cover change research at a national or international level (FAO, 1996; Skole et al., 1997). This type of remote sensing can be done every 5–10 years, in combination with low-level remote sensing. The Face Foundation in the Netherlands and Winrock International have used satellite imagery for evaluating forestry projects (Face Foundation, 1997; MacDicken, 1998). Remote sensing has been used by several researchers in measuring deforestation in tropical forests in Central and South America (e.g., Dale et al., 1994; Sanchez-Azofeifa et al., 1997; Sanchez-Azofeifa and Quesada-Mateo, 1995; Skole and Tucker, 1993; Stone et al., 1991). Attempts to estimate biomass from remote sensors have generally been costly and have had mixed results (MacDicken, 1997). To date, no one has measured carbon using remote sensing (Brown, 1996; MacDicken, 1997).

Skole et al. (1997) have proposed an international system for monitoring land cover change which includes studies in specific locations for field validation and accuracy assessments for the large area analyses; these sites could also be useful for evaluating project impacts, if integrated with the approach described next.

4.2.2.2. Low-level remote sensing. Using aerial photography, videography, and orthophotographs, photographs of land areas can be taken on an annual basis to see whether the project is proceeding according to design. Field/site measurements and ground truthing will also need to be conducted periodically.

4.2.3. Field/site measurements

Field/site measurements include two types of techniques (biomass surveys and destructive sampling) which can be used together in monitoring carbon in forestry projects.

4.2.3.1. Biomass surveys. Biomass surveys can include one or more of the following methods: research studies; surveys; the monitoring of wood production and end products; and forest inventories. Research studies use intensive data collection and analysis methodologies to typically test research hypotheses. Surveys of project field activities are conducted to see what was actually implemented in the project. This type of monitoring would provide useful data for the evaluation of GHG reduction and sequestration projects, especially if the surveys are combined with other approaches. The monitoring of wood production and end product data is needed to develop historical and trend data for the development of accurate baselines. An account needs to be made of what happens to the wood once it is felled or trees and branches die. If dead wood is regularly collected, it should be measured and its use recorded.

Carbon inventories can be performed at virtually any level of precision desired by inventory sponsors and provide flexibility in the selection of methods, depending on the costs and benefits of monitoring. Monitoring systems need to assess the net difference in each carbon pool for project and nonproject (or pre-project) areas over a period of time. By comparing these changes in the project area to changes in pools unaffected by project activities (i.e. comparison plots), the monitoring effort can assess the impact of the project on carbon storage. Detailed biomass measurement methods can be found in MacDicken (1998).

4.2.3.2. Destructive sampling. Destructive sampling is the oldest methodology for estimating biomass density at a site. It involves selection of representative sites in the ecosystem (usually a few square meters each, and in a few rare cases as large as one hectare each). All the vegetation is uprooted and the pertinent parameters obtained, e.g., volume, weight at different moisture contents, proportions of various components like branches, stem and roots, and chemical composition of the biomass. Detritus is also collected and similarly analyzed. This is usually accompanied with similar measurements of parameters of interest in the soil profile, including soil layers, structure, texture and cation exchange capacity, organic carbon, inorganic nutrients, etc.

4.3. Baseline use: re-estimating the baseline

For JI (Article 6) and CDM (Article 12) projects implemented under the Kyoto Protocol, the emissions reductions from each project activity must be "additional to any that would otherwise occur," also referred to as "additionality criteria" (Articles 6.1b and 12.5c). Determining additionality requires a baseline for the calculation of carbon sequestered, i.e., a description of what would have happened to the carbon stock had the project not been implemented (see Violette et al., 1998). Additionality and baselines are inextricably linked and are a major source of debate (Trexler and Kosloff, 1998). Determining additionality is inherently problematic because it requires resolving a counter-factual question: What would have happened in the absence of the specific project?

Because investors and hosts of forestry projects have the same interest in a forestry project (i.e., they want to get maximum carbon sequestration from the project), they are likely to overstate and over-report the amount of carbon saved by the project (e.g., by overstating business-as-usual changes to the carbon stock). Cheating may be widespread if there is no strong monitoring and verification of the projects. Even if projects are well monitored, it is still possible that the real amount of carbon saved is less than estimated values. Hence, there is a critical need for the establishment of realistic and credible baselines.

Future changes in carbon stock may differ from past levels, even in the absence of the project, due to growth, technological changes, input and product prices, policy or regulatory shifts, social and population pressure, market barriers, and other exogenous factors. Consequently, the calculation of the baseline needs to account for likely changes in relevant regulations and laws, and changes in key variables (e.g., population growth or decline, and economic growth or decline, deforestation, development of markets for wood products, and how future land use patterns (e.g., gradual deforestation) affect the carbon cycle).

Ideally, when first establishing the baseline, carbon stocks should be measured for at least a full year before the date of the initiation of the project. The baseline will be re-estimated based on monitoring and evaluation data collected during project implementation. In some cases, allometric equations for estimating carbon emissions may be used, but only under special conditions. Finally, in order to be credible, project-specific baselines need to account for free riders.

4.3.1. Free riders

It is possible that forestry projects are undertaken by participants who would have conducted the same activities if there had been no project and, therefore, the carbon sequestered by these "free riders" would not be perceived as "additional" to what would otherwise have occurred (Vine, 1994). Although free riders may be regarded as an unintended consequence of a forestry project, free ridership should still be estimated, if possible, during the estimation of the baseline. While free riders can also cause leakage and positive project spillover, these impacts are typically considered to be insignificant compared to the impacts from other participants.

The most common method of developing an estimate of free ridership is to ask project developers what they would have done in the absence of the project (also referred to as "but for the project" discussions). Based on answers to carefully designed survey questions, participants are classified as free riders (yes or no). There are at least two problems in using this approach: (1) very inaccurate levels of free ridership may be estimated, due to questionnaire wording; and (2) there is no estimate of the level of inaccuracy, for adjusting confidence levels.

4.3.2. Performance benchmarks

Concerned about an arduous project-by-project review that might impose prohibitive costs, some researchers have proposed an alternate approach, based on a combination of performance benchmarks and procedural guidelines that are tied to appropriate measures of output (e.g., Lashof, 1998; Michaelowa, 1998; Swisher, 1998; Trexler and Kosloff, 1998). In all cases, measurement and verification of the actual performance of the project is required. The performance benchmarks for new projects could be chosen to represent the high-performance end of the spectrum of current commercial practice (e.g., representing roughly the top 25th percentile of best performance). In this case, the benchmark serves as a goal to be achieved. In contrast, others might want to use benchmarks as a reference or default baseline: an extension of existing technology, and not representing the best technology or process.

A panel of experts could determine a baseline for a number of project types, which could serve as a benchmark for the UNFCCC. This project categorization could be expanded to a categorization by regions or countries, resulting in a region-by-project matrix. Project developers could check the relevant element in the matrix to determine the baseline of their project. Most of the costs in this approach relate to the establishment of the matrix and its periodical update. Before moving forward with this approach, analysis is needed to consider the costs in developing the matrix and its update, the potential for projects to qualify, and the potential for free riders. The US EPA is assessing the feasibility and desirability of implementing a benchmark approach for evaluating additionality (e.g., see Hagler Bailly, 1998).

4.3.3. Comparison groups

For some projects, the comparison of the amount of carbon storage achieved under a project with the amount that would have been achieved without the project requires monitoring the project area as well as nonproject comparison sites prior to project startup. One can have comparison plots within the project area or outside the project area to supplement the sites within the project area. To establish the internal validity of the evaluation results, the comparison plots must be similar enough to the project area so that they can serve as a proxy for the project area under the assumption that the project was not implemented.[5] Similarity can be established on the basis of the key factors that determine biomass productivity: rainfall, temperature, insolation, soil characteristics, species and land management. Land management is the most difficult criterion to meet since it could diverge significantly between comparison site and project areas. By selecting comparison plots within the project area, these divergences can be eliminated or minimized. Also, there is no general way to ensure that the comparison plots will remain valid throughout the life of the project; special care and monitoring are needed.

4.4. Project case: monitoring and evaluation

4.4.1. Project leakage

Leakage occurs because the project boundary within which a project's benefits are calculated may not be able to encompass all potential indirect project effects. In this paper, negative indirect effects are referred to as "project leakage" while positive indirect effects are referred to as "positive project spillover". For example, projects affecting the supply of timber products can affect price signals for the rest of the market, potentially counteracting a portion of the calculated benefits of the project: the establishment of forestry plantations could lead to a decrease in timber prices, leading to a higher incentive to convert forests to agricultural purposes. Another example of leakage occurs when a forest preservation project involves protecting land that was previously harvested by the local population for their personal consumption as fuel wood (MacDicken, 1998; Watt et al., 1995). Although this area is now protected from harvesting, people from the surrounding communities still require wood for fuel and construction. Preserving this forest area has shifted their demand for fuel wood to a nearby site, leading to increased deforestation. This off-site deforestation will at least partially offset the carbon sequestration at the project site. Furthermore, some projects may involve international leakage: e.g., in 1989, when all commercial logging in Thailand was banned, the logging shifted to neighboring countries such as Burma, Cambodia and Laos as well as to Brazil (Watt et al., 1995).

4.4.2. Positive project spillover

When measuring changes in carbon stock, it is possible that the actual reductions in carbon are greater than

[5] This is particularly important when trying to estimate deforestation rates for protected areas. The estimation of deforestation rates is critical in establishing project baselines, and slight changes in the estimates of deforestation can significantly affect the amount of carbon saved by a carbon offset project (see Busch et al., 1999).

measured because of changes in participant behavior not directly related to the project, as well as to changes in the behavior of other individuals not participating in the project (i.e., nonparticipants). These secondary impacts stemming from a forestry project are commonly referred to as "positive project spillover". Project spillover may be regarded as an unintended consequence of a forestry project; however, as noted below, increasing project spillover may also be perceived as a strategic, intended mechanism for reducing GHG emissions.

The intent of some forestry projects is often not only to induce project developers to adopt certain forestry measures, but more broadly to transform neighboring areas for implementing similar measures. For example, in the Rio Bravo Carbon Sequestration Pilot Project, other projects have been implemented to preserve forests, catalyzed by the successful launch of the Rio Bravo project (Programme for Belize, 1997). In the CARE/Guatemala project, which increased fuelwood availability and agricultural productivity by providing trees through CARE-sponsored tree nurseries, the project's techniques have been adopted in other areas beyond the project's boundaries by participants setting up their own tree nurseries (Brown et al., 1997).

Positive project spillover effects can occur through a variety of channels including: (1) project participants that undertake additional, but unaided, forestry measures based on positive experience with the project; (2) wood product manufacturers changing the nature of their products, to reflect the demand for more wood products created through the project; (3) governments adopting new forestry policies and legislation because of the results from one or more forestry projects; (4) technology transfer efforts by project participants which help reduce market barriers throughout a region or country; or (5) the emergence of ecotourism.

In the beginning stages of a project, project leakage and positive project spillover are likely to be modest, so that the MERVC of such impacts may not be a priority. These effects are also likely to be insignificant or small for small projects and for certain types of projects. Under these circumstances, it may be justified to disregard these impacts. This would help reduce MERVC costs. As the projects become larger or are more targeted to market transformation, these impacts should be evaluated. As an example, in the Rio Bravo Carbon Sequestration Pilot Project, secondary impacts were deemed to be significant if the impacts resulted in an alteration in emissions of 5000 t C/yr or above (i.e., 20% of the 1 million t C estimated to be sequestered through the purchase of forested land, or 200,000 t C, divided by the 40 years of the project life) (Programme for Belize, 1997). Furthermore, to be "clearly and directly" attributable to the project, the secondary impacts had to manifest themselves within 1 year (Programme for Belize, 1997); for the evaluation of forestry projects, longer periods (e.g., 5 years) may be necessary.

4.4.3. Market transformation

Project spillover is related to the more general concept of "market transformation", defined as: "the reduction in market barriers due to a market intervention, as evidenced by a set of market effects, that lasts after the intervention has been withdrawn, reduced or changed" (Eto et al., 1996). In contrast to project spillover, increasing market transformation is expected to be a strategic mechanism (i.e., an intended consequence) for reducing carbon emissions in the forestry sector for the following reasons:

- To increase the effectiveness of forestry projects: e.g., by examining market structures more closely, looking for ways to intervene in markets more broadly, and investigating alternative points of intervention.
- To reduce reliance on incentive mechanisms: e.g., by strategic interventions in the market place with other market actors.
- To take advantage of regional and national efforts and markets.
- To increase focus on key market barriers other than cost.
- To create permanent changes in the market.

As a hypothetical example, consider a bioenergy project that grows trees on a rotational basis and harvests the trees as an energy resource for a community hospital. The developer of the project needs to make sure there are no technical, financial, administrative, or policy barriers to the implementation of this project, and to determine if there are other large, energy-intensive end users who could take advantage of this resource (e.g., industrial customers?). The project developer could also examine what partnering opportunities exist for promoting the bioenergy project (e.g., developing a voluntary labeling program that labels customers as "green energy users"). Once the labeling program is in place, additional projects might emerge, creating an expanded market for bioenergy projects. Finally, the developer could try to extend the proposed labeling program to other regions, in order to enlarge the market for the project's trees.

Two examples in the forestry sector show the beginnings of market transformation: (1) the availability of improved biomass cook stoves, an important technology for reducing deforestation, has influenced many nonparticipants to purchase cook stoves as these programs develop (Bialy, 1991); and (2) a reduced impact logging project in Malaysia is being replicated in Brazil and other parts of Indonesia (personal communication from Pedro Moura-Costa, EcoSecurities, Ltd., Sept. 15, 1998; Jepma, 1997).

Most evaluations of market transformation projects focus on market effects (e.g., Eto et al., 1996; Schlegel et al., 1997): the effects of forestry projects on the structure of the market or the behavior of market actors that lead to increases in the adoption of forestry products, services, or practices. In order to claim that a market has been transformed, project evaluators need to demonstrate the following (Schlegel et al., 1997):

- There has been a change in the market that resulted in increases in the adoption and penetration of forestry technologies or practices.
- That this change was due at least partially to a project (or program or initiative), based both on data and a logical explanation of the program's strategic intervention and influence.
- That this change is lasting, or at least that it will last after the project is scaled back or discontinued.

The first two conditions are needed to demonstrate market effects, while all three are needed to demonstrate market transformation. The third condition is related to persistence: if the changes are not lasting (i.e., they do not persist), then market transformation has not occurred. Because fundamental changes in the structure and functioning of markets may occur only slowly, evaluators should focus their efforts on the first two conditions, rather than waiting to prove that the effects will last.

To implement an evaluation system focused on market effects, one needs to carefully describe the scope of the market, the indicators of success, the intended indices of market effects and reductions in market barriers, and the methods used to evaluate market effects and reductions in market barriers (Schlegel et al., 1997). Evaluation activities will include one or more of the following: (1) measuring the market baseline; (2) tracking attitudes and values; (3) tracking sales; (4) modeling of market processes; and (5) assessing the persistence of market changes (Prahl and Schlegel, 1993). As one can see, these evaluation activities will rely on a large and diverse group of data collection and analysis methods, such as: (1) surveys of customers, forestry companies, forestry manufacturers, government organizations, etc.; (2) analytical and econometric studies of cost data and sales data; and (3) process evaluations.

5. Environmental and socioeconomic impacts

The Kyoto Protocol exhorts developed countries, in fulfilling their obligations, to minimize negative social, environmental and economic impacts, particularly on developing countries (Articles 2.3 and 3.14). Furthermore, one of the primary goals of the CDM is sustainable development. At this time, it is unclear on what indicators of sustainable development need to be addressed in the evaluation of forestry projects. Once there is an understanding of this, then MERVC guidelines for those indicators will need to be designed. At a minimum, forestry projects should meet current country guidelines for non-CDM projects.

The persistence of GHG reductions and the sustainability of forestry projects depend on individuals and local organizations that help support a project during its lifetime. Both direct and indirect project benefits will influence the motivation and commitment of project participants. Hence, focusing only on GHG impacts would present a misleading picture of what is needed in making a project successful or making its GHG benefits sustainable. In addition, a diverse group of stakeholders (e.g., government officials, project managers, non-profit organizations, community groups, project participants, and international policymakers) are interested in, or involved in, forestry projects and are concerned about their multiple impacts.

5.1. Environmental impacts

Forestry projects have widespread and diverse environmental impacts that go beyond GHG impacts. The environmental benefits associated with forestry projects can be just as important as the global warming benefits. Direct and indirect project impacts need to be examined, as well as "avoided negative environmental impacts" (e.g., the deferral of the construction of a new power plant). Both gross and net impacts need to be evaluated.

At a minimum, evaluators need to evaluate the environmental impacts associated with the project. Evaluators need to collect some minimal information on potential impacts via surveys or interviews with key stakeholders. The evaluator should also check to see: (1) whether any existing laws require these impacts to be examined, (2) if any proposed mitigation efforts were implemented, and (3) whether expected positive benefits ever materialized. Evaluators may want to conduct some short-term monitoring to provide conservative estimates of environmental impacts. The extent and quality of available data, key data gaps, and uncertainties associated with estimates should be identified and estimated.

5.2. Socioeconomic impacts

In examining socioeconomic impacts, evaluators need to ask the following questions: who the key stakeholders are, what project impacts are likely and upon what groups, what key social issues are likely to affect project performance, what the relevant social boundaries and project delivery mechanisms are, and what social conflicts exist and how they can be resolved. To address these questions, evaluators could conduct informal sessions with representatives of affected groups and relevant non-governmental organizations.

After a project has been implemented, MERVC activities should assess whether the project led to any social and economic impacts and whether any mitigation was done. Direct and indirect project impacts need to be examined, as well as "avoided negative socioeconomic impacts" (e.g., the preservation of an archaeological site as a result of the deferral of the construction of a new power plant). Evaluators should collect some minimal information on potential impacts via surveys or interviews with key stakeholders. The evaluator should also check to see if any proposed mitigation efforts were implemented and whether expected positive benefits ever materialized. The extent and quality of available data, key data gaps, and uncertainties associated with estimates may need to be identified and estimated.

6. Reporting

Reporting refers to *measured* GHG and non-GHG impacts of a project (in some cases, organizations may report on their *estimated* impacts, prior to project implementation, but this is not the focus of these guidelines). Reporting occurs throughout the MERVC process (e.g., periodic reporting of monitored results and a final report once the project has ended). LBNL has developed a Monitoring and Evaluation Reporting Form (MERF) that evaluators may follow when reporting changes in carbon stock (see Vine et al., 1999).

6.1. Multiple reporting

Several types of reporting might occur in forestry projects: (1) impacts of a particular project could be reported at the project level and at the program level (where a program consists of two or more projects); (2) impacts of a particular project could be reported at the project level and at the entity level (e.g., a utility company reports on the impacts of all of its projects); and (3) impacts of a particular project could be reported by two or more organizations as part of a joint venture (partnership) or two or more countries. To mitigate the problem of multiple reporting, project-level reporters should indicate whether other entities might be reporting on the same activity and, if so, who. If there exists a clearinghouse with an inventory of stakeholders and projects, multiple reporting might not constitute a problem. For example, in their comments on an international emissions trading regime, Canada (on behalf of Australia, Iceland, Japan, New Zealand, Norway, Russian Federation, Ukraine and the United States) proposed a national recording system to record ownership and transfers of assigned amount units (i.e., carbon offsets) at the national level (UNFCCC, 1998). A synthesis report could confirm, at an aggregate level, that bookkeeping was correct, reducing the possibility of discrepancies among Parties' reports on emissions trading activity.

7. Verification and certification

If carbon credits become an internationally traded commodity, then verifying the amount of carbon reduced or fixed by projects will become a critical component of any trading system. Investors and host countries may have an incentive to overstate the GHG emissions reductions from a given project, because it will increase their earnings when excessive credits are granted; as an example, these parties may overstate baseline emissions or understate the project's emissions. To resolve this problem, there is a need for external (third party) verification.

As part of the verification exercise, an overall assessment of the quality and completeness of each of the GHG impact estimates needs to be made by requesting information in a Verification Reporting Form (VRF), similar to the MERF. For forestry projects, verifying baseline and post-project conditions may involve inspections, spot measurement tests, or assessments, as well as requesting documentation on key aspects of the project. In addition, the following general questions need to be asked: (1) have the monitoring and evaluation methods been well documented and reproducible? (2) have the results been checked against other methods? and (3) have results been compared for reasonableness with outside or independently published estimates? At this time, certification is expected to simply be the outcome of a verification process: i.e., no other monitoring and evaluation activities are expected to be conducted.

8. Costs

Monitoring and evaluation costs will depend on what information is needed, what information and resources are already available, the size of the project area, the monitoring methods to be used, and frequency of monitoring. Furthermore, some methods require high initial costs: e.g., in remote sensing, start-up costs in terms of equipment and personnel training may make a one-time digital image survey prohibitively expensive, while making multiple surveys exceedingly cost effective. The cost for monitoring a forestry project in India has been estimated at 8.5% of the total project cost, and it seems that monitoring similar projects would not exceed 10% of the total cost (Ravindranath and Bhat, 1997). In some cases, the monitoring and evaluation costs can be as high as 20% (personal communication from Margo Burnham, The Nature Conservancy, Jan. 28, 1999).

Due to the availability of funding, we realize that some project developers and evaluators will not be able to conduct the most data intensive methods proposed in this paper; however, we expect each project to undergo some evaluation and verification in order to receive carbon credits (especially, certified emission reduction units).

Moreover, we believe that monitored projects will save more carbon and offset the cost of the monitoring because: (1) installations following a monitoring and evaluation protocol should come in near or even above the projected level of carbon sequestration; and (2) installations with some measurement of carbon sequestration should tend to have higher levels of sequestered carbon initially and experience carbon sequestration levels that remain high during the lifetime of the project. In the end, the cost of monitoring and evaluation will be partially determined by its value in reducing the uncertainty of carbon credits: e.g., will one be able to receive carbon credits with a value greater than 10% of project costs that are spent on monitoring and evaluation?

Because of concerns about high costs, MERVC activities cannot be too burdensome: in general, the higher the costs, the less likely organizations and countries will try to develop and implement forestry projects. However, in some cases, due to the enormous cost differential between the carbon reduction options of UNFCCC Parties, fairly high costs can be accommodated before these costs become prohibitive. Nevertheless, MERVC costs should be as low as possible. In sum, actual (as well as perceived) MERVC costs may discourage some transactions from occurring. Tradeoffs are inevitable, and a balance needs to be made between project implementation and the level of detail (and costs) of MERVC reporting guidelines.

Project estimates of impacts could be adjusted, based on the amount of uncertainty associated with the estimates, without conducting project-specific analyses. Projects with less accurate or less precisely quantified benefit estimates would have their estimates adjusted and therefore have their benefits rendered policy-equivalent to credits from projects that can be more accurately quantified. The US Environmental Protection Agency's Conservation Verification Protocol reward more rigorous methods of verifying energy savings by allowing a higher share of the savings to qualify for tradable SO_2 allowances. Three options are available for verifying subsequent-year energy savings: monitoring, inspection and a default option (USEPA, 1995, 1996). In the *monitoring option*, a utility can obtain credit for a greater fraction of the savings and for a longer period: biennial verification in subsequent years 1 and 3 (including inspection) is required, and savings for the remainder of physical lifetimes are the average of the last two measurements. The monitoring option requires a 75% confidence in subsequent-year savings (like in the first year). In contrast, the *default option* greatly restricts the allowable savings: 50% of first-year savings, and limited to one-half of the measure's lifetime. For the *inspection option* (confirming that the measures are both present and operating): a utility can obtain credit for 75% of first-year savings for units present and operating for half of physical lifetime (with biennial inspections), or 90% of first-year savings for physical lifetimes of measures that do not require active operation or maintenance (e.g., building shell insulation, pipe insulation and window improvements). Thus, utilities could use a simpler evaluation method at a lower cost and receive fewer credits, or they could use a more sophisticated method and receive more credits. A similar system could be applied to the crediting of forestry projects.

9. Summary

Monitoring and evaluation of forestry projects is needed to accurately determine their impact on the carbon stock other attributes, and to ensure that the global climate is protected and that country obligations are met. Articles 6 and 12 of the Kyoto Protocol require MERVC activities. The challenges to successful monitoring and evaluation will not be insignificant: e.g., the evaluation of project leakage, positive project spillover, market transformation, and free riders. LBNL has developed MERVC guidelines that address these issues by describing methods, procedures, and forms which can be used in preparing monitoring and evaluation plans and in reporting the results of monitoring, evaluation, and verification (Vine et al., 1999). The next phase of LBNL's work will be to develop a procedural handbook providing information on how one can complete monitoring, evaluation and verification forms. We then plan to test the usefulness of these handbooks in the real world.

Acknowledgements

We would like to thank Maurice N. LeFranc, Jr. of the U.S. Environmental Protection Agency, Climate Policy and Program Division, Office of Economics and Environment, Office of Policy, Planning and Evaluation for his assistance. This work was supported by the US Environmental Protection Agency through the US Department of Energy under Contract No. DE-AC03-76SF00098.

References

Bialy, J., 1991. Improved Cookstove Programs in Sri Lanka: Perceptions of Success, Country Studies No. 3. In: Improved Biomass Cookstove Programs: A Global Evaluation. East-West Center, Honolulu, Hawaii.

Bird, D., Ross, N., Ruiz Corzo, M., 1998. Problems and solutions associated with an aij project: an example from a forest management project in Central Mexico. In: Riemer, P., Smith, S., Thambimuthu, K. (Eds.), Greenhouse Gas Mitigation: Technologies for Activities Implemented Jointly. Elsevier Science Limited, Oxford, UK, pp. 209–214.

Brown, K., 1996. The utility of remote sensing technology in monitoring carbon sequestration agroforestry projects. Winrock International Institute for Agricultural Development, Arlington, VA.

Brown, S., 1997. Estimating biomass and biomass change of tropical forests: a primer. FAO Forestry Paper 134. Food and Agricultural Organization of the United Nations, Rome, Italy.

Brown, P., Cabarle, B., Livernash, R., 1997. Carbon Counts: Getting the Numbers Right. World Resources Institute, Washington, DC.

Busch, C., Sathaye, J., Sanchez-Azofeifa, A., 1999. Lessons for greenhouse gas accounting: a case study of costa rica's protected areas project. LBNL-42289, Lawrence Berkeley National Laboratory, Berkeley, CA.

Colwell, R. (Ed.), 1983. Manual of Remote Sensing. American Society of Photogrammetry. Fall Church, VA.

Dale, V., O'Neil, R., Southworth, F., Pedlowski, M., 1994. Causes and effects of land-use change in Central Rondonia, Brazil. Photogrammetric Engineering and Remote Sensing 59, 997–1005.

De Jong, B., Tipper, R., Taylor, J., 1997. A framework for monitoring and evaluating carbon mitigation by farm forestry projects: example of a demonstration project in Chiapas, Mexico. Mitigation and Adaptation Strategies for Global Change 2, 231–246.

Eto, J., Prahl, R., Schlegel, J., 1996. A scoping study on energy-efficiency market transformation by California utility DSM programs.. LBNL-39058, Lawrence Berkeley National Laboratory, Berkeley, CA.

Face Foundation, 1997. Annual Report 1996. Face Foundation, Arnheim, The Netherlands.

Faeth, P., Cort, C., Livernash, R., 1994. Evaluating the carbon sequestration benefits of forestry products in developing countries. World Resources Institute and US Environmental Protection Agency, Washington, DC.

Food and Agricultural Organization (FAO) of the United Nations, 1996. Forest resources assessment 1990: survey of tropical forest cover and study of change processes. FAO Forestry Paper 130. Food and Agricultural Organization of the United Nations, Rome, Italy.

Hagler Bailly, 1998. Evaluation of using benchmarks to satisfy the additionality criterion for joint implementation projects. Prepared for the US Environmental Protection Agency, Hagler Bailly, Boulder, CO.

Hamburg, S., Zamolodchikov, D., Korovin, G., Nefedjef, V., Utkin, A., Gulbe, J., Gulbe, T., 1997. Estimating the carbon content of Russian forests: a comparison of phytomass/volume and allometric projections. Mitigation and Adaptation Strategies for Global Change 2, 247–265.

Jepma, C., 1997. Reduced-impact logging in Indonesia. Joint Implementation Quarterly 3, 2.

Lashof, D., 1998. Additionality under the clean development mechanism. Natural Resources Defense Council, New York, Unpublished.

MacDicken, K., 1997. Project specific monitoring and verification: state of the art and challenges. Mitigation and Adaptation Strategies for Global Change 2, 191–202.

MacDicken, K., 1998. A Guide to Monitoring Carbon Storage in Forestry and Agroforestry Projects. Winrock International Institute for Agricultural Development, Arlington, VA.

Marland, G., Schlamadinger, B., Canella, L., 1997. Forest management for mitigation of CO_2 emissions: how much mitigation and who gets the credits? Mitigation and Adaptation Strategies for Global Change 2, 303–318.

McLain, H., 1998. Global carbon impacts of using forest harvest residues for district heating in Vermont, Proceedings of the 1998 ACEEE Summer Study, Vol. 9. American Council for an Energy-Efficient Economy, Washington, DC, pp. 105–117.

Michaelowa, A., 1998. Joint implementation—the baseline issue: economic and political aspects. Global Environmental Change 8, 81–92.

U.S. Department of Energy (USDOE), 1994. General Guidelines for the Voluntary Reporting of Greenhouse Gases Under Section 1605(b) of the Energy Policy Act of 1992, Vol. 1. DOE/PO-0028, US Department of Energy, Washington, DC.

Parton, W., Ojima, D., Schimel, D., 1995. Models to evaluate soil organic matter storage and dynamics. In: Carter, M., Stewart, B. (Eds.), Structure and Organic Matter Storage in Agricultural Soils. Lewis Publishers, New York, pp. 421–448.

Prahl, R., Schlegel, J., 1993. Evaluating market transformation. Proceedings of the 1993 International Energy Program Evaluation Conference. National Energy Program Evaluation Conference, Chicago, IL, pp. 469–477.

Programme for Belize, 1997. Rio Bravo carbon sequestration pilot project, operating protocols, introduction. Programme for Belize.

Ravindranath, N.H., Bhat, P.R., 1997. Monitoring of carbon abatement in forestry projects—case study of Western Ghat project. Mitigation and Adaptation Strategies for Global Change 2, 217–230.

Sanchez-Azofeifa, G., Quesada-Mateo, C., 1995. Deforestation, carbon dynamics, and sustainable mitigation measures in Costa Rica: The Puerto Viego de Sarapiqui case study. Interciencia 20, 396–400.

Sanchez-Azofeifa, G., Skole, D., Chomentowski, W., 1997. Sampling global deforestation databases: the role of persistence. Mitigation and Adaptation Strategies for Global Change 2, 177–189.

Schlamadinger, B., Marland, G., 1996. The role of forest and bioenergy strategies in the global carbon cycle. Biomass and Bioenergy 10, 275–300.

Schlegel, J., Prahl, R., Raab, J., 1997. Nest steps for evaluation of market transformation initiatives: an update to the NARUC guidebook. In: Schlegel, J., Goldberg, M., Raab, J., Prahl, R., Keneipp, M., Violette, D. (Eds.), Evaluating Energy-Efficiency Programs in a Restructured Industry Environment: A Handbook for PUC Staff. National Association of Regulatory Utility Commissioners, Washington, DC (Chapter 4).

Schroeder, P., Brown, S., Mo, J., Birdsey, R., Cieszewski, C., 1997. Biomass estimation for temperate broadleaf forests of the United States using inventory data. Science 43, 424–434.

Skole, D., Justice, C., Townshend, J., Janetos, A., 1997. A land cover change monitoring program: strategy for an international effort. Mitigation and Adaptation Strategies for Global Change 2, 157–175.

Skole, D., Tucker, C., 1993. Tropical deforestation and habitat fragmentation in the Amazon: Satellite data from 1978 to 1988. Science 260, 1905–1910.

Slater, P., 1980. Remote Sensing: Optics and Optical Systems. Addison-Wesley Publishing Co. Inc., Reading, MA.

Smith, P., Powlson, D., Smith, J., Elliott, E. (Eds.), 1997. Evaluation and comparison of soil organic matter models. Geoderma 81, 1–225.

Stone, T., Brown, I., Woodwell, G., 1991. Estimation by remote sensing of deforestation in Central Rondonia, Brazil. Forest Ecology and Management 38, 291–304.

Swisher, J., 1998. Project baselines and additionality in the clean development mechanism. Presented at The Aspen Global Forum, Aspen, CO.

Trexler, M., Haugen, C., Loewen, L., 1992. Global warming mitigation through forestry options in the tropics, In: Sampson, R., Hair, D. (Eds.), Forests and Global Change, Vol. 1: Opportunities for Increasing Forest Cover 73. American Forests, Washington, DC.

Trexler, M., Kosloff, L., 1998. The 1997 Kyoto Protocol: what does it mean for project-based climate change mitigation? Mitigation and Adaptation Strategies for Global Change 3, 1–58.

UNEP/WMO Information Unit on Climate Change, 1992. United Nations framework convention on climate change. UNEP/WMO Information Unit on Climate Change, Geneva, Switzerland.

UNFCCC, 1997. Kyoto Protocol to the United Nations framework convention of climate change. FCCC/CP/1997/L.7/Add.1, Dec. 10, 1997. At UNFCCC Web site (under CC:INFO Products): http://www.unfccc.de/ccinfo.

UNFCCC, 1998. Review of the implementation of commitments and of other provisions of the convention. Activities Implemented Jointly: Review of Progress Under the Pilot Phase (Decision 5/CP.1), FCCC/CP/1998/INF.3. At UNFCCC Web site (under CC:INFO Products): http://www.unfccc.de/ccinfo.

US Environmental Protection Agency (USEPA), 1995. Conservation and Verification Protocols, Version 2.0. EPA 430/B-95-012, US Environmental Protection Agency, Washington, DC.

US Environmental Protection Agency (USEPA), 1996. The User's Guide to the Conservation and Verification Protocols, Version 2.0. EPA 430/B-96-002, US Environmental Protection Agency, Washington, DC.

Vine, E., 1994. The human dimension of program evaluation. Energy—The International Journal 19, 165–178.

Vine, E., Sathaye, J., 1997. The monitoring, evaluation, reporting, and verification of climate change mitigation projects: discussion of issues and methodologies and review of existing protocols and guidelines. LBNL-40316, Lawrence Berkeley National Laboratory, Berkeley, CA. This report can be downloaded via the World Wide Web: http://eetd.lbl.gov/ea/ccm/ccPubs.html.

Vine, E., Sathaye, J., Makundi, W., 1999. Guidelines for the monitoring, evaluation, reporting, verification, and certification of forestry projects for climate change mitigation. LBNL-41877, Lawrence Berkeley National Laboratory, Berkeley, CA. This report can be downloaded via the World Wide Web: http://eetd.lbl.gov/ea/ccm/ccPubs.html.

Violette, D., Ragland, S., Stern, F., 1998. Evaluating Greenhouse Gas Mitigation through DSM Projects: Lessons Learned from DSM Evaluation in the United States. Hagler Bailly Consulting, Inc., Boulder, CO.

Watt, E., Sathaye, J., de Buen, O., Masera, O., Gelil, I., Ravindranath, N., Zhou, D., Li, J., Intaraprvich, D., 1995. The institutional needs of joint implementation projects. LBL-36453, Lawrence Berkeley National Laboratory, Berkeley, CA.

Wilkie, D., Finn, J., 1996. Remote Sensing Imagery for Natural Resources Monitoring: A Guide for First-Time Users. Columbia University, New York, NY.